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TRANSPORTATION SAFETY RISK FOR SOURCE RECOVERY VS. CONSEQUENCE OF LEAVING RADIOACTIVE SOURCES IN PLACE AND VULNERABLE DUE TO LIMITED TRANSPORT OPTIONS OR DENIAL OF SHIPMENT

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ABSTRACT

This paper discusses potential risks associated with transportation safety of recovered radioactive sources in normal commerce versus latent risk of not recovering the disused radioactive sources due to limited transport options or outright denial of shipment. It is essential, during each phase of the recovery process, to ensure secure, timely, cost effective, and reliable means to return vulnerable radioactive sources to safe and protected locations by land, sea, and/or air transport. In some cases, only limited transport options exist or denials of shipment may occur that impede the recovery process. It is argued that the risks associated with normal transportation of recovered sources are significantly less than the risks related to leaving disused radioactive sources at their current location.

INTRODUCTION

The Off-Site Source Recovery Project (OSRP) at Los Alamos National Laboratory (LANL), as part of the National Nuclear Security Administration's (NNSA) Office of Global Threat Reduction, recovers and manages excess and unwanted radioactive sealed sources that present a risk to public health and safety; and sources for which few or no disposal options currently exist.

Sources containing radioactive plutonium, americium, californium, cesium, cobalt, radium, and strontium have been recovered from medical, educational, agricultural, research, industrial, and government facilities. Since 1999, OSRP has been able to recover nearly 16,000 sources from more than 600 sites in 49 States, the D.C. area, Puerto Rico, and a number of foreign countries. This represents recovery of over 172,000 Curies of radioactive material in less than ten years.[1]

The problem of excess and unwanted radioactive material widely distributed around the world is recognized as a global threat. Unused long-lived radioactive sources are the residual product of industry, medicine, and scientific research. These unwanted sources create a stockpile of hazardous material which could be incorporated into a weapon of terror; or may simply present a health and safety threat to the public and the environment if left unattended.

There are several root causes to the legacy radioactive source problem which are not addressed in this discussion. However, one of the most vivid obstacles to a seemingly simple solution (i.e.,

[1] OSRP source recovery totals as of September 15, 2007.

expeditious, efficient, and cost effective elimination of the threat posed by unwanted radioactive sources by moving them to a safe and secure location) is the restricted or limited transportation mechanisms available to move such materials from a place of high vulnerability to safe and secure locations. Therefore, any difficulty in shipping these at-risk sources may result in the sources remaining at-large – with potential adverse effects to public health or the environment.

The question thus becomes whether the potential risks associated with transportation safety of recovered radioactive sources in normal commerce are greater than or less than the latent risks of not recovering the disused radioactive sources due to limited transport options or outright denial of shipment.

RADIOACTIVE SOURCE DISTRIBUTION

Since their development, radioactive sources have been distributed around the world for peaceful uses in medicine, industry, agriculture, research, and in common consumer products. Radioactive sources are prevalent in hospitals, irradiation facilities, construction companies, universities, factories, oil field industry, and even homes throughout the world (Ferguson, et al. 2003).

Millions of small radioactive sources (containing ^{226}Ra, ^{137}Cs, etc.) exist around the world, each containing small amounts of radioactivity (Martellini & McLaughlin 2005). Individually they pose little risk to public health or the environment. However, potential danger to public health or the environment increases if these sources are consolidated in large numbers at a single location without proper protection.

Larger, higher-activity sources are also prevalent. Estimates indicate that more than 10,000 medical teletherapy units are located at hospitals throughout the world for treatment of cancer (Ibid). Such devices often contain many thousands of curies of ^{60}Co each. Blood irradiators use hundreds of curies of ^{137}Cs to kill antibodies in blood products to prevent host-vs.-graft disease. It is estimated that between 1,000 and 2,000 blood irradiators exist worldwide (Strub & Van Tuyle 2003).

Approximately 500,000 sources were distributed to European Union Member States over the past 50 years and about 110,000 remain in use (Angus, et al. 2000). Most of the remainder were returned to manufacturers; or sent to secure interim storage or disposition. However, the sources at greatest risk of being lost from regulatory control are the estimated 30,000 disused sources held in storage at users' premises throughout the European Union Member States (Ibid).

A definitive number of radioactive sealed sources distributed worldwide is not currently known, nor easily obtainable. A survey conducted in 2003 found that a total of about 7.8 million radioactive sealed sources were in use worldwide for various applications (GAO 2003).[2] It is even more difficult to determine the precise number of radioactive sources that have been lost, stolen, abandoned, illegally transferred, or improperly dispositioned. The full extent of the global threat from excess and unwanted radioactive sealed sources cannot be accurately quantified. Unfortunately, the problem is dynamic; and it is not getting any smaller.

SOURCE LIFECYCLE

The lifecycle of radioactive sealed sources begins with raw materials and manufacturing, and should terminate with final disposition.[3] Figure 1 attempts to convey possible stages in the lifecycle of a sealed radioactive source.

[2] Only 49 out of 127 IAEA member states responded to the GAO survey in 2003. Note: According to the U.N., there are currently 193 sovereign states with general international recognition.

[3] A proactive cradle-to-grave management approach is one way to monitor status/location of radioactive sources.

Vulnerability of sources at each stage in the lifecycle varies. Intentional misuse, theft, or accidental loss may occur at any point in the lifecycle during storage, transportation, or use. However, when sources are no longer in use (e.g., relegated to indefinite storage), the potential for loss, theft, abandonment, improper disposition, and/or an unfortunate incident seems more likely. Therefore, a key issue for management of radioactive sources is to identify exactly when they become unwanted or disused. When sources are unwanted, they should be returned to the manufacturer, sent for disposition, or source recovery operations for threat reduction purposes should be initiated.

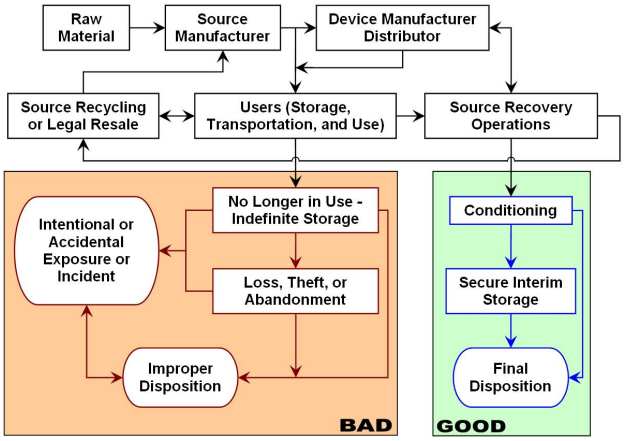

Figure 1: Lifecycle of Sealed Sources

(The diagram in Figure 1 was inspired by other generic source lifecycle diagrams, such as those appearing in Angus, et al., 2000; Ferguson, et al., 2003; Ferguson and Potter 2005; and Van Tuyle, et al., 2005.)

In this simplified graphic model, three lifecycle terminus options exist: (1) safe, secure, and legal final disposition on the "good" side, or (2) improper disposition and/or (3) intentional or accidental exposure or incident on the "bad" side.

The arrows represent transportation and flow of the source from one stage to another. If transportation is hindered due to denial of shipment, sources cannot proceed to the next stage of their journey and may never reach final disposition.

DENIAL OR DELAY OF SHIPMENT

Denials of shipment of radioactive material negatively influence the recovery of excess, unwanted, or abandoned sources of radiation for risk mitigation purposes. Impediments to this recovery process lead to delays in returning at-risk radioactive sources to safe and protected environments; and leaves them in a potentially "bad" situation as represented in Figure 2.

If recovery shipments cannot be made or are delayed, the hazards associated with the radioactive sources at the storage location are not reduced. Therefore, the material is still subject to possible loss, theft, abandonment, improper disposition, and/or an unfortunate incident.

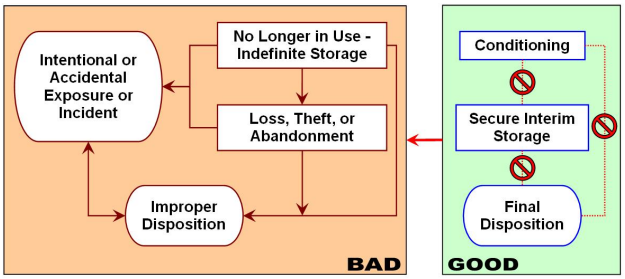

Figure 2: Denial of Shipment Leaves Unwanted Sources in a "Bad" Situation

Ensuring efficient and cost effective means of domestic and international shipment of excess, unwanted, or abandoned sources of radiation for risk mitigation purposes is vital to global threat reduction and the health and safety of people around the world. Therefore, shipments of radioactive sources for risk mitigation purposes should not be denied (or delayed).[4] Denial of such recovery shipments of at-risk radioactive sources are not in the public interest.

COMPARING RISKS

Is the potential risk associated with transportation safety of recovered radioactive sources in normal commerce greater than or less than the latent risks of not recovering excess, unwanted, or abandoned radioactive sources and leaving them in place?

Take them or leave them…"That is the question. Whether 'tis nobler in the mind to suffer the slings and arrows of outrageous fortune or to take arms against a sea of troubles…" [5]

For this discussion we hope to answer whether it is better to "take arms against a sea of troubles" by transporting them in the public domain; or to "suffer the slings and arrows of outrageous fortune" by leaving at-risk sources unrecovered.

Recovery Transportation Risks – "Take Them"

As alluded to by the arrows in Figure 1, production and use of radiation sources inevitably involves transport in the public domain. When sources are no longer in use they must also be shipped through the public domain to safe and protected interim storage or final disposition.

There are some inherent risks associated with normal, incident-free[6] transport (e.g., radiation dose to transport workers). Although risks such as these are important in some cases, for the purposes of this document risks from incident-free transport are assumed to be minimal. Transport of this sort simply results in successful movement of radioactive source(s) from one location to another without negative impact to people, property, or the environment along the shipping route.

Occurrences during transport may have different outcomes depending on the severity of the accident or incident, the type/magnitude of failure of package integrity, and the radiological and physical characteristics of the material conveyed (IAEA 2003). Despite herculean efforts to ensure safe transport of radioactive sources related to packaging, potential for accidents or incidents in transit does not equal zero.

The nature of the safety requirements incorporated into established transport regulations[7] for shipment of Class 7 cargo[8] ensures high levels of protection of the public and the environment. In fact, radioactive material has been shipped within the U.S. for over 50 years with no occurrences of death or serious injury from exposure to the radioactive cargo (DOE 2007). Despite this fact, fears of potential accidents/incidents which result in loss of package containment and subsequent dispersal of radioactive material into the environment often taint public or political opinions against transport of Class 7 cargo. This is a 'perception' issue, not a real radiation safety issue.

As previously stated, potential for accidents or incidents during transport does not equal zero, but can this be quantified? We have to look at past performance.

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[4] Assuming the packages are prepared in accordance with established transportation regulations and carried in compliance with established international hazardous material codes.

[5] Quotation from Hamlet's soliloquy in Act III, Scene I of Shakespeare's play "Hamlet, Prince of Denmark."

[6] Incident-free means transport activity in which no accident or other negative incident occurs.

[7] For example, IAEA Regulations for Safe Transport of Radioactive Material (TS-R-1).

[8] Class 7 cargo includes all radioactive material shipments.

In the U.S., approximately 2,800,000 shipments of radioactive material occur every year (DOT 1998). Thus over a ten year period, about 28 million shipments take place. Historical records for the ten-year period from 1997 through 2006 show that the U.S. recorded a total of 163,875 reportable domestic transportation-related incidents[9] involving hazardous material.[10] Of these, only 147[11] involved shipments of radioactive cargo (DOT 2007). Most of these incidents were minor vehicular accidents which did not cause adverse effects to the Class 7 packages.

Although accidents or incidents are inevitable, it appears the odds are quite low. Perhaps one out of every 200,000 shipments of radioactive cargo may result in an accident. If an accident does occur, an actual radiation hazard may not occur since the packages used for Class 7 cargo are designed and tested to survive accident conditions without release of the radioactive constituents.

Risks of not Recovering Unwanted Sources – "Leave Them"

Recently, international cooperative efforts have been undertaken to upgrade the security of specific facilities around the world; and to put more effective security controls and regulations in place (Bunn & Bunn 2001). The majority of this focus has been on securing nuclear materials and nuclear facilities, not other types of radioactive material. Despite these efforts, hundreds of tons of nuclear material, in dozens of countries around the world, remain dangerously vulnerable to theft (Bunn & Weir 2006).

If unused sources are stored in a secure environment prior to proper disposition, source recovery may not be necessary. Unfortunately, internationally organized secure-in-place efforts have little effect on radioactive sources which have not been relocated to a centralized repository; or sources that have otherwise fallen through the cracks of regulatory control. This may include millions of sources currently used[12] or stored at individual facilities around the world for medical, industrial, agricultural, or research purposes (each with various levels of regulatory control and oversight).

Because limited transport options exist or denials of shipment occur to impede the recovery process, some at-risk sources may inevitably be left behind. Since safety, security, and control standards at these locations may be less than desirable, the risk of loss, theft, abandonment, improper disposition, and/or an unfortunate incident involving these lingering sources is not reduced. Over the years, lost, abandoned, stolen, or improperly dispositioned sources have caused unfortunate radiation contamination incidents and deaths around the world – sometimes accidental, sometimes intentional. According to a database compiled by researchers at Stanford University's Institute for International Studies, 830 entries were recorded in their "Database on Nuclear Smuggling, Theft, and Orphan Radiation Sources," as of 2002 (Trei 2002). This included 643 nuclear smuggling incidents (including thefts), 107 cases of orphaned sources, and more than 80 cases involving fraud or malevolent acts using radioactive material to commit murder, deliberate exposure and blackmail, and to poison food and water supplies (Ibid). At least some of these incidents may have been prevented if the sources were moved to a safe and secure environment *before* they were lost, abandoned, stolen, or misused.

When comparing potential transportation risks to risks caused by leaving disused, unwanted, or abandoned radioactive sources in place, the answer is clear. If safe management of radioactive

[9] These incident reports to the U.S. Dept. of Transportation are required by 49 CFR Part 171, Sections 15 and 16.
[10] Includes all modes of transport (air, highway, rail, and water) and all hazardous material cargo (Class 1-9).
[11] This value represents less than 0.0006% of the total number of radioactive material shipments; or less than 0.1% of the total number of reported incidents.
[12] All sources currently in use will reach the end of their useful life someday, and will require proper disposition.

sources is not guaranteed where the unused sources exist, it is less risky to "take them" than it is to "leave them."

CONCLUSIONS

The full extent of the global threat from excess and unwanted radioactive sealed sources cannot be accurately quantified. This dynamic problem changes as new sources are distributed around the world and old sources out-live their usefulness.

Since late 2001, the U.S. and the European Union have contributed large sums of money at home and internationally to secure and/or recover at-risk radioactive sources. So far, this only addresses a small fraction of disused radioactive sources worldwide.

Sources that are no longer in use (e.g., relegated to indefinite storage) are more vulnerable to intentional misuse, theft, or accidental loss. Therefore, it is important to identify exactly when radioactive sources are no longer used or are unwanted. When sources become unwanted, they should be returned to the manufacturer or sent for disposition; or source recovery operations for threat reduction purposes should be initiated.

Ensuring reliable and affordable means of domestic and international shipment of excess, unwanted, or abandoned sources for risk mitigation purposes is vital to global threat reduction and the health and safety of people around the world. Denial of such recovery shipments of at-risk radioactive sources are not in the public interest.

Risks during transportation of radioactive sources for threat reduction purposes are less than latent risks associated with not recovering excess, unwanted, or abandoned radioactive sources. If enduring security and management of radioactive sources cannot be guaranteed for disused sources where they currently exist, logic dictates that source recovery operations be conducted to relocate excess and unwanted sources to a safe and secure location for threat reduction purposes.

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